Late improvement in graft patency after coronary artery bypass grafting: Serial assessment with multidetector computed tomography in the early and late postoperative settings

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Objective: Grafts initially showing poor patency after coronary artery bypass grafting have occasionally shown improvement on serial multidetector computed tomography. This study analyzed possible factors associated with this phenomenon.

Methods: Between September 2003 and July 2007, 512 patients underwent multidetector computed tomography within 1 month of isolated coronary artery bypass grafting. Among them, 1720 distal anastomoses were made with 1042 arterial and 302 venous conduits. Of these, 95 grafts (in 73 patients) were faint (n = 67) or nonvisualized (n = 28). Seventy-three of these grafts (in 56 patients) had follow-up multidetector computed tomographic evaluation 1 year after surgery and comprised the study group.

Results: Improvement in graft patency (faint to patent or nonvisualization to visualization) occurred in 44 grafts (60.3%). Multivariate analysis revealed proximal target vessel stenosis of at least 90% (relative risk, 3.81; *P* = .009), larger target coronary size (relative risk, 1.72; *P* = .002), and radial artery graft use (relative risk, 4.44; *P* = .003) to be significantly associated with the graft patency restoration. Graft patency restoration was most commonly observed in a group of 28 radial artery grafts that were anastomosed to target vessel with proximal stenosis of at least 90%; of these grafts, 24 (85.7%) showed improved graft patency on follow-up.

Conclusions: A large proportion of radial artery grafts initially showing poor opacification after coronary artery bypass grafting demonstrated patency restoration on serial multidetector computed tomography. Larger target vessel size and target vessel stenosis of at least 90% were significant correlative factors. (J Thorac Cardiovasc Surg 2011;142:793-9)

ACD

Recently, multidetector-row computed tomography (MDCT) has gained rapid acceptance as a diagnostic cardiac imaging modality, allowing noninvasive visualization of anastomosed grafts after coronary artery bypass grafting (CABG) with high spatial resolution. With 16-channel MDCT, preliminary data indicated excellent sensitivity (99%) and specificity (98%) for complete occlusion and fair sensitivity (88%) for significant stenosis of at least 50% in coronary arteries.[1,2]

From early 2000, serial MDCT evaluation was routinely used for post-CABG patients in our institution. Evaluation began during the early postoperative period (<1 week) and was performed at 1 year and then biennially thereafter. Data from serial MDCT evaluations allowed us to perform long-term assessments of graft patency after CABG in a large patient population. This observation of a relatively large number of patients revealed that grafts that initially showed poor patency (nonvisualization or faint visualization) occasionally showed improvement on late follow-up MDCT (Figure 1). This finding stands in contrast to the common supposition that graft patency decreases with time after CABG.

It would be valuable to know how many of the patients with poorly patent grafts on initial MDCT will have an improvement in graft patency, because those bypassed segments with later improvements may not be candidates for repeated revascularization. We therefore investigated the late improvement in graft patency after CABG to determine how frequently this phenomenon is observed. Furthermore, to address the clinical significance of this phenomenon, we performed univariate and multivariate analyses to determine factors that are associated with this improvement.

MATERIALS AND METHODS

Patients

Patients who underwent diagnostic quality 16- or 64-channel coronary MDCT angiography within 1 month and again at 1 year after isolated CABG and had faint or nonvisualized grafts at the initial MDCT comprised

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
ITA	= internal thoracic artery
MDCT	= multidetector-row computed tomography
RA	= radial artery
SVG	= saphenous vein graft

the study population. Between September 2003 and July 2007, a total of 724 patients underwent isolated CABG (2534 distal anastomoses). Excluded were patients who did not undergo postoperative MDCT coronary angiograms within 1 month of surgery because of early death (n = 8), renal dysfunction (n = 67), or refusal to undergo MDCT evaluation (n = 76). Also excluded were those with poor MDCT image quality (n = 61) as a result of arrhythmia, lung atelectasis, severe obesity, or clip artifacts. This resulted in a population of 512 patients. Among them, a total of 1720 distal anastomoses were made (3.36 per patient) with 499 left internal thoracic artery (ITA) grafts, 10 right ITA grafts, 512 radial artery (RA) grafts, 21 gastroepiploic artery grafts, and 302 saphenous vein grafts (SVGs). Ninety-five grafts in 73 patients showed faintness (n = 67, 3.8%) or nonvisualization (n = 28; 1.6%) on MDCT within 1 month of surgery. Of these 73 patients, 11 patients (14 grafts) were excluded because they were evaluated with different MDCT scanners (the 16-channel MDCT and the 64-channel MDCT scanners were used for initial and follow-up evaluations, respectively). Another 6 patients (8 grafts) were excluded because they were not reevaluated with MDCT angiography. Of those 6 patients, 4 were in clinically stable condition (5 faint RA conduits), 1 underwent percutaneous coronary stenting for an occluded SVG bypassed to a posterior descending artery, and 1 died of bleeding after a pericardial window operation for the treatment of postoperative pericardial effusion. This last patient had a faint left ITA graft to a left anterior descending artery and faint RA graft to an obtuse marginal branch. Finally, 73 grafts (76.8%) in 56 patients had follow-up MDCT with the same MDCT scanner type (16- or 64-channel MDCT) at 1 year after surgery. These 73 grafts were analyzed, and the outcomes of these grafts on MDCT reevaluation was the subject of this study.

The study protocol was approved by the institutional review board. The requirement for informed patient consent was waived by the board because of the retrospective nature of this study.

Surgical Techniques

Each surgical procedure was conducted by 1 of 4 cardiac surgeons (H.S., S.J.C., C.H.C., J.W.L.). All surgeons were experienced and had performed a minimum of 500 CABG procedures before the study. The harvest of the RA graft or SVG was simultaneous with that of the left ITA graft. The RA graft was dissected en bloc as a vascular pedicle together with the satellite veins with a harmonic scalpel. Arterial harvesting was performed only after adequate systemic heparinization had been achieved. For the RA graft antispasmodic pretreatment, topical papaverine was gently applied intraluminally immediately after harvesting. The distal coronary anastomoses were performed with continuous 8-0 polypropylene sutures. The RA or SVG aortic anastomosis was performed with continuous 6-0 or 7-0 polypropylene sutures after creation of a 3.5-mm circular punch defect (SCANLAN Single-Use Aorta/Vein Punches; Scanlan International, Saint Paul, Minn).

Postoperative Medication

As an antispasmodic measure, intravenous diltiazem was administered continuously at a dose of 1 to 2 μg/(kg $\cdot$ min); administration started in the operating room and continued while the patient was in the intensive care unit. After discharge from the intensive care unit, diltiazem was administered orally and continued for at least 6 months. With regard to platelet inhibition, daily aspirin (100 mg) and clopidogrel (75 mg) were routinely administered as soon as patients were extubated. Anticoagulation with heparin or warfarin was only performed for patients with risk factors for thromboembolism.

Coronary Artery Imaging

The degree of target vessel stenosis was determined by preoperative conventional angiography. Digital coronary angiograms were retrospectively analyzed on bypassed coronary segments to assess the diameter of native coronary segments. Maximal luminal diameter distal to the stenotic lesions was regarded as the diameter of bypassed native coronary segments. Before November 2006, coronary MDCT angiograms were performed with a 16-channel MDCT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany); thereafter, a dual-source MDCT scanner (Somatom Definition; Siemens Medical Solutions), an upgraded version of the 64-channel MDCT scanner, was used (12 patients and 15 grafts at the initial [<1 month] evaluation and 21 patients and 27 grafts at follow-up). Consequently, 11 patients (14 grafts) were evaluated with different imaging modalities, with the 16-channel MDCT and the 64-channel MDCT used for initial and follow-up evaluations, respectively. These patients were excluded from the subject population as previously described to avoid the problems originating from any differences in sensitivity and specificity in assessing graft patency between the 2 scanners. Finally, 62 grafts in 47 patients were evaluated with 16-channel MDCT, whereas 11 grafts in 9 patients were evaluated with 64-channel MDCT.

In the presence of nonoliguric renal dysfunction or failure, MDCT was performed after preprocedural *N*-acetylcysteine medication and appropriate hydration for consenting patients only. The parameters of 16-channel MDCT were as follows: temporal resolution of 165 ms, spatial resolution of $0.5 \times 0.5 \times 0.75$ mm, and tube output of 120 kV at 500 milliamperes per second (mAs). The parameters of 64-channel MDCT were as follows: temporal resolution of 83 ms, spatial resolution of $0.4 \times 0.4 \times 0.6$ mm, and tube output of 100 to 120 kV at 200 to 380 mAs/rotation. Electrocardiographic synchronization was done by retrospective gating in both devices. The pitch, which was dependent on the heart rate, averaged 0.3 with the 64-channel MDCT, whereas it was fixed to 0.2 with 16-channel MDCT. Images were acquired in a single breath-holding interval in the craniocaudal direction from the lung apex to the costophrenic angles. Contrast agent (70–100 mL Iomeron 400; Bracco Imaging SpA, Milan, Italy) was injected intravenously at a rate of 4 mL/s, followed by 40 mL saline solution at the same rate.

The graft patency status was classified into 1 of 3 descriptive imaging categories: patent, faint (visualization but with significant stenosis, $\geq$50% of luminal narrowing, or string sign), or nonvisualized (total occlusion). Poor, stringy visualization was represented by luminal enhancement but threadlike narrowing along the entire length of the graft. In assessing the sequential bypass grafts, each anastomosis in the sequential bypass grafts were considered as a separate graft. Improvement in graft patency on follow-up MDCT evaluation was defined as transition (1) from faint to patent or (2) from nonvisualization to visualization (Figure 1).

All coronary MDCT angiograms were reviewed at the date of MDCT scanning on daily basis by a single experienced radiologist (J-W.K.). During the MDCT reviews, brief operation records were referenced to see which grafts were anastomosed to which epicardial arteries, but preoperative coronary angiography data and clinical status were not referenced.

Data Analysis

Data are expressed as mean $\pm$ SD for continuous variables and as numbers with percentages for categoric variables. To identify factors associated with late improvement in graft patency, univariate analysis was performed with the Pearson χ^2 test (or Fisher's Exact test) or independent *t* test. For multivariate analysis, the logistic regression method was used. Variables

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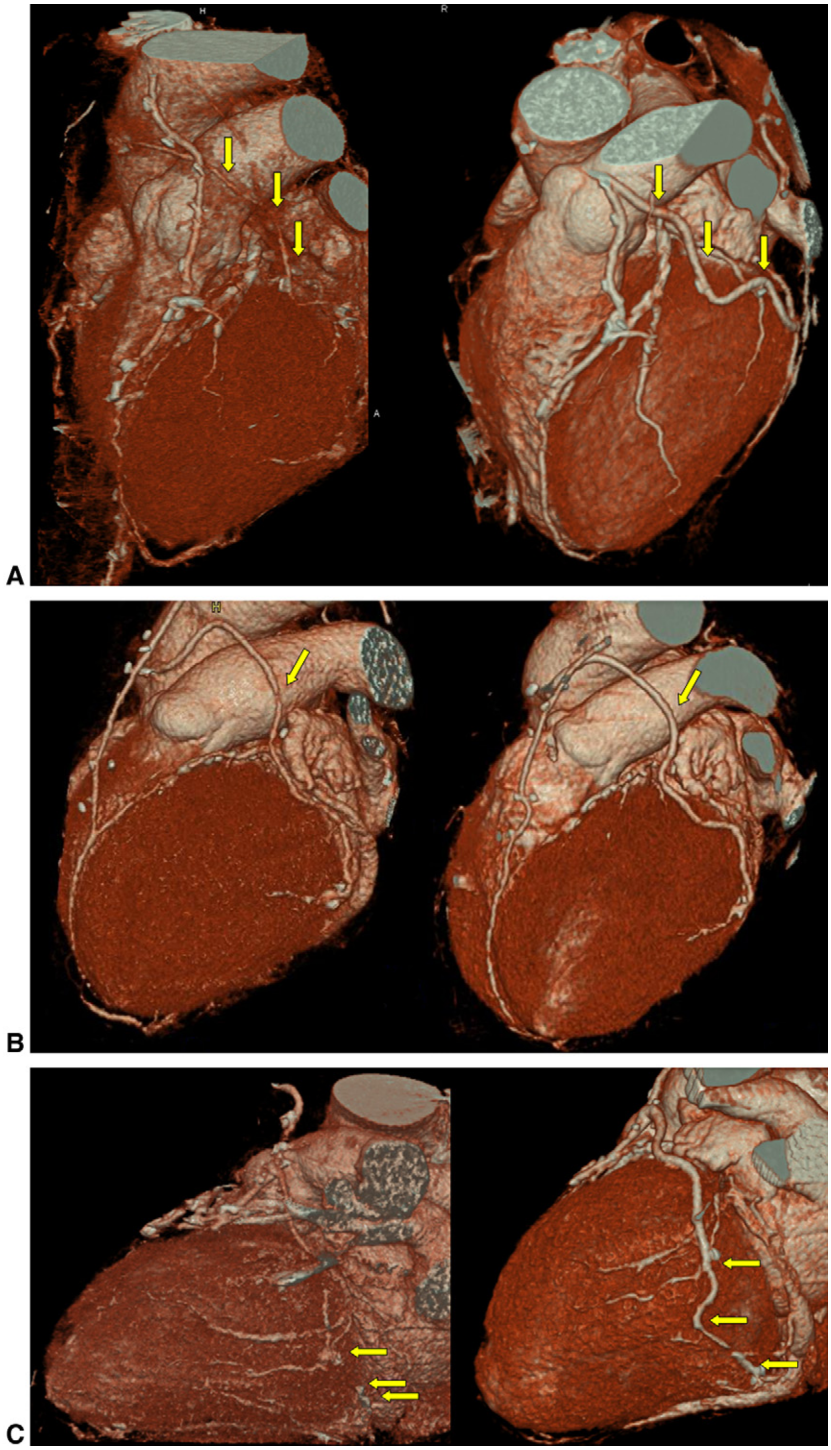

FIGURE 1. Examples of improved graft flow on serial coronary computed tomographic angiography after surgery are shown (A and B, 64-channel computed tomography; C, 16-channel computed tomography). Two radial artery grafts bypassed to obtuse marginal branches show diffuse (A) or focal (B) stenosis on initial examinations *(left, arrows)* and improve to full patency with increased luminal diameter on follow-up evaluations *(right, arrows).* Another graft bypassed to left circumflex territory (C) is not seen beyond first obtuse marginal branch on initial computed tomography *(left, arrows);* however, restored patency in that segment, as well as improved luminal filling in proximal segment, is observed on later examination *(right, arrows).*

with a *P* value no greater than .20 in univariate analyses were candidates for the multivariate models. Multivariate analyses involved a backward elimination technique, and only variables with a *P* value less than .10 were used in the final model. Results were expressed as relative risk with 95% confidence intervals. SPSS software version 14.0 (SPSS Inc, an IBM Company, Chicago, Ill) was used for statistical analyses.

TABLE 1. Baseline characteristics of patients who underwent isolated coronary artery bypass grafting during the study period

	Subjects	Excluded	*P* value
No. of patients	56	668	
No. of bypassed segments	73	2461	
Age (y, mean ± SD)	61.4 ± 9.1	62.0 ± 8.4	.58
Male (no.)	39 (69.6%)	497 (74.4%)	.43
Body mass index (kg/m^2, mean ± SD)	25.7 ± 3.7	25.5 ± 3.2	.80
Diabetes mellitus (no.)	16 (28.6%)	238 (35.6%)	.29
Systemic hypertension (no.)	27 (48.2%)	336 (50.3%)	.76
Dyslipidemia (no.)	25 (44.6%)	271 (40.6%)	.55
Current smoker (no.)	10 (17.9%)	104 (15.6%)	.65
Urgent operation (no.)	6 (10.7%)	38 (5.7%)	.13
Preoperative intra-aortic balloon pump insertion (no.)	2 (3.6%)	21 (3.1%)	.86
Serum creatinine (mg/dL, mean ± SD)	1.0 ± 0.3	1.0 ± 0.6	.76
Left ventricular ejection fraction (%, mean ± SD)	57.2% ± 11.4%	56.4% ± 10.7%	.63
Target location (no. of grafts)			.002
Left anterior descending	15 (20.5%)	765 (31.1%)	
Left circumflex	43 (59.0%)	1477 (60.0%)	
Right coronary artery	15 (20.5%)	219 (8.9%)	
Target stenosis			.08
<90% (no. of grafts)	39 (53.4%)	1058 (43.0%)	
≥90% (no. of grafts)	34 (46.6%)	1403 (57.0%)	
Off-pump coronary artery bypass grafting (no.)	21	281	.51
Sequential bypassing (no. of grafts)			.47
Yes	24	911	
No	49	1550	
Radial artery proximal anastomosis (no. of grafts)			.60
T-graft to left internal thoracic artery	18	183	
Direct aortic	41	486	

Numbers refer to numbers of patients unless number of grafts is specified.

RESULTS

Baseline characteristics of patients who underwent isolated CABG during the study period are shown in Table 1. There were no significant differences in baseline profiles between the included and excluded populations except for the bypassed target coronary artery territory. In the subject population (n = 56), 21 patients (37.5%) underwent off-pump surgery. Early mortality was reported for 1 patient as a result of postoperative low cardiac output syndrome. There were 1 perioperative myocardial infarction, 1 case of neurologic injury, 1 case of sternal wound infection, and 2 cases of sternal bleeding requiring reoperation.

Of the 73 grafts that could be followed-up at 1 year after CABG, 54 were faint and 19 were nonvisualized on the initial evaluations. Initial MDCT findings were nonvisualization for all SVGs, whereas faint visualization was the main finding for arterial grafts ($P < .001$; Figure 2). On follow-up, 41 grafts were patent, 7 were faint, and 25 were nonvisualized. As a result, improvement in graft patency occurred in 44 grafts (60.3%), which comprised 39 RA grafts, 3 left ITA grafts, and 2 SVGs. A total of 38 of 54 grafts (70.4%) that had initially been classed as faint had improved patency, whereas only 6 of 25 grafts (24.0%) that had initially been classed as nonvisualized showed improvement on follow-up MDCT ($P < .001$).

Of the 54 arterial grafts (5 left ITA grafts and 49 RA grafts) that were initially categorized as showing faint visualization, 6 (all RA grafts) had focal stenosis (3 proximal, 2 midshaft, 1 distal), whereas the other 48 grafts showed diffuse narrowing or string signs. Of the 6 RA grafts with focal stenosis, 5 recovered the opacification on follow-up assessments. Of 48 arterial grafts (5 left ITA grafts and 43 RA grafts) with diffuse narrowing or string signs, in the later assessments 13 (2 left ITA grafts and 11 RA grafts) showed nonvisualization, 3 (all RA grafts) continued to show diffuse narrowing, and 32 (3 left ITA grafts and 29 RA grafts) had become widely patent.

When comparisons were made between the different types of graft conduit used, the only difference was found between RA and SVG conduits. RA grafts showed more frequent improvement in patency ($P = .023$). Details of improvement in graft patency are shown in Figure 2.

Deterioration in graft opacification occurred in 13 grafts in 12 patients, including 11 RA grafts and 2 left ITA grafts, which were initially faint and later non-visualized.

Among the 73 bypassed segments, the target vessel diameter could be measured in 68 segments (93.2%). The graft segments with improved patency had greater target vessel size than did those without improvement (2.18 mm vs 1.82 mm, $P = .002$). Univariate and multivariate analyses to determine factors associated with late improvement in graft patency revealed that proximal target vessel stenosis of at least 90% and larger target coronary size on preoperative conventional coronary angiography and RA graft rather than SVG use were independent factors for graft patency restoration (Table 2).

Subgroup analysis showed that the graft patency restoration was most commonly observed in a group of 28 RA grafts that were anastomosed to target vessels with proximal stenosis of at least 90%. Of these grafts, 24 (85.7%) showed improved graft patency on follow-up evaluation. In particular, 3 of 5 nonvisualized grafts in this group were restored to full patency.

DISCUSSION

This study investigated the prognosis of poor-patency bypassed grafts after CABG by serial MDCT evaluations. The number of poorly visualized grafts on initial MDCT

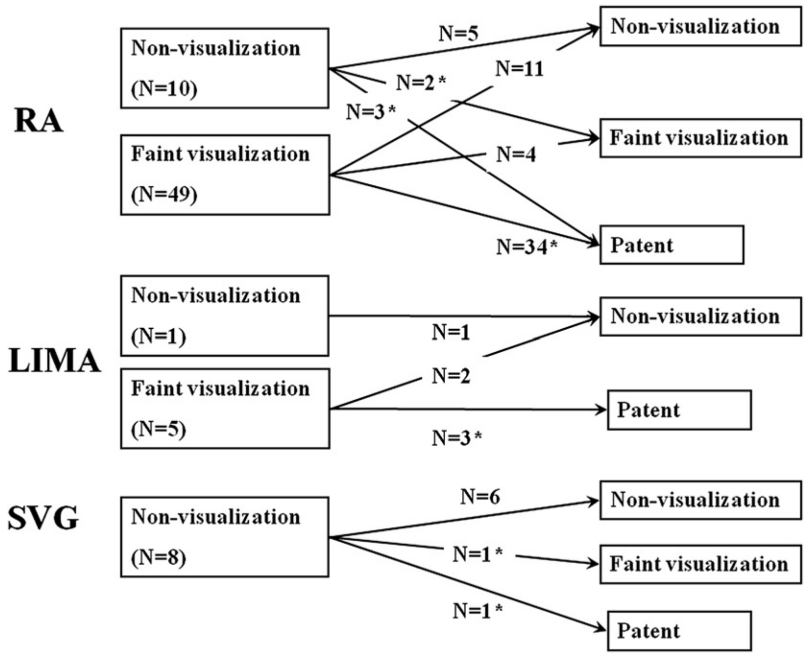

FIGURE 2. Details of improvement in patency according to type of graft are shown. Of faint or nonvisualized grafts on initial assessment *(left boxes),* 44 showed improved findings on late follow-up *(right boxes). RA,* Radial artery graft; *LIMA,* left internal thoracic artery graft; *SVG,* saphenous vein graft.

evaluation was sufficient for statistical analyses because a large patient population was recruited in this study. The study found that a large proportion of grafts that initially showed occlusion or poor opacification demonstrated patency restoration on late follow-up. RA graft use and target vessel stenosis of at least 90% were significantly correlated with this phenomenon.

Similar findings were observed in a number of studies with conventional coronary angiography during the early and late postoperative periods after CABG.[3,4] One study involving 23 post-CABG patients reported that 1 RA graft found to be occluded on initial evaluation had improved to a diffuse narrowing by late follow-up. Furthermore, the mean values of luminal RA and left ITA graft diameters significantly increased during the interval of follow-up.[3] Another study, by Possati and colleagues,[4] also revealed luminal dilatation of the RA graft in 68 patients, from 2.09 to 2.58 mm, during 5-year follow-up. In that study, parietal graft irregularities documented in 7 cases by early angiography had disappeared after 5 years; in 1 case, a RA graft judged to be occluded reduction in the hyperspastic characteristics of RA with time. The findings of our study support these previous results and show that similar results are obtained with MDCT. Whereas the cited studies had focused on the increase in luminal diameter with time, and the improved patency was observed only a limited number of patients (1 and 8, respectively), this study focused on analyses of only the poorly patent grafts by sorting them out from a much larger patient population. Although the reversible nature of arterial graft stenosis after CABG has been reported, the exact rate of the improvement in patency was not known. This was attributable to the difficulty that the repetition of invasive coronary angiography was the only method to evaluate the incidence of patency restoration. The introduction of MDCT and its popularization in post-CABG settings has enabled us to assess the graft patency routinely. Consequently, the number of poorly patent grafts analyzed in this study was enough to perform statistical analyses. Around 66% of initially poorly visualized RA grafts had improvement. These findings are still remarkable because, to the best of our knowledge, there have been no data dealing with the issue on the improvements in graft patency over time after CABG with coronary computed tomographic angiography.

Histologically, the RA has a fenestrated internal elastic lamina and a thicker wall than the ITA, with a higher density of myocytes in its media, accounting for its well-recognized propensity toward early graft spasm relative to the ITA.[5,6] For SVGs, 3 entities are known to be responsible for graft failure: thrombosis, intimal hyperplasia, and graft atherosclerosis.[7] Of these, thrombosis accounts for graft failure within the first month after CABG and may be related to endothelial injury and technical errors. Graft–target size mismatch, poor vessel runoff, and competitive flow will produce low flow through the graft conduit and may also lead to early thrombosis.[7] Unlike graft spasm, which frequently occurs in RA grafts in early postoperative period, SVG thrombosis rarely resolves spontaneously. The results of this study, showing a greater tendency for the RA graft to

TABLE 2. Univariate and multivariate analyses to determine factors associated with late improvement in graft patency

	Univariate	Multivariate		
	P value	RR	95% CI	*P* value
Clinical profile				
Female sex	.38			
Age	.88			
Body mass index	.77			
Current smoking	.091			
Diabetes mellitus	.37			
Urgent operation	.59			
Coronary lesions				
Target territory	.60			
Left anterior descending	Reference			
Left circumflex	.40			
Right coronary artery	>.99			
Target vessel size	.002	1.72	1.58–2.36	0.002*
Degree of proximal stenosis (≥90%)	.004	3.81	1.54–9.02	0.009*
Procedural factors				
Off-pump vs on-pump coronary artery bypass grafting	.13			
Grafts	.072			0.01*
Left internal thoracic artery	.33	2.01	0.21–12.92	0.38
Radial artery	.025	4.44	1.37–10.10	0.003*
Saphenous vein graft	Reference		Reference	
Composite T–grafting	.51			
Sequential anastomosis	.20			
Imaging modality (16- vs 64-channel computed tomography)	.50			

RR, Relative risk; *CI,* confidence interval. *$P < .05$.

recover its patency more frequently than the SVG, is reflective of the difference in mode of early graft failure between the 2 conduits, thrombosis versus spasm.

The advantages of computed tomographic coronary angiography are that it is noninvasive and less expensive than conventional coronary angiography; also, complementary evaluation of extracardiac anatomic features provides useful information.[8,9] The accuracy of MDCT coronary angiography has been extensively evaluated in the post-CABG setting. An analysis of pooled data showed the sensitivity and specificity of the detection of complete occlusions with 16-slice MDCT to be 99% and 98%, respectively. The positive predictive value for complete occlusion with 16-slice MDCT was 94% (75 of 80 patients; 95% confidence interval, 86%–97%).[10,11]

Calcific deposits or metal objects and irregular or rapid heart rhythms severely interfere with the images obtained by MDCT.[10,11] Motion artifacts are less common with imaging of CABG conduits than natural coronary arteries.[12]

In this study, target vessel stenosis of at least 90% was significantly associated with late improvement in graft patency. The relationship between the severity of proximal native vessel stenosis and bypassed graft patency has been previously reported for arterial grafts in several studies.[13-15] In 1 previous study, target coronary vessel lesions with stenosis of at least 90% were associated with a lower rate of occlusion of the RA graft and a lower rate of the string sign in RA grafts than were target coronary vessel lesions with stenosis of 70% to 89%.[16] Certain characteristics of the RA, such as increased wall thickness and myocyte organization, may increase the likelihood of spasm under conditions of decreased or competitive flow.[17] Some investigators have shown, however, that inducible ischemia is uncommon in myocardial areas supplied by grafts with an angiographic string sign; reversible ischemia was detected in the distributions of only 2 of 14 string signs.[18]

Little is known about the clinical implications of performing routine MDCT coronary angiography in patients undergoing CABG. In cases with an abnormal early MDCT coronary angiography, such as were in this study, we started anticoagulation therapy for SVGs or increased the dosage of coronary vasodilator (nitrate, calcium-channel blockers) for arterial graft problems, despite the lack of evidence of beneficial effects of these methods to prevent clinically relevant ischemia. The study results revealed, however, that although poorly patent grafts were frequently found on early MDCT coronary angiography in post-CABG patients, clinically relevant ischemia was rare. Consequently, some authors of this report (J.B.K., H.S., C.H.C.) have since become skeptical about performing compute tomographic coronary angiography routinely for patients in clinically stable condition because of the results from this study. Furthermore, because only patients with stable conditions are able to undergo MDCT evaluations, the role of MDCT is thought to be limited in patients with serious ischemia in the early postoperative settings. In this critical situation, conventional coronary angiography might be a better option than MDCT, because MDCT may not differentiate the cause of ischemia, whereas conventional angiography can clearly differentiate between the occlusion and spasm of grafts (through infusion of intracoronary vasodilator) or between graft problems and distal native coronary lesions.

Radiation dose is an important consideration related to the use of MDCT. With 64-channel MDCT, radiation dosage is estimated to be 9.6 to 15.2 mSv in men and 13.5 to 21.4 mSv in women, which is double the dose in invasive coronary angiography.[19,20] Although there are no universally accepted dose limits, this may be of limited relevance in the elderly population, given that they are reported to be less susceptible to the lifetime risk of radiation exposure for any given dose.[19-21] Cautions must be given to younger patients, however, who are at greater risks of lifelong radiation exposure and consequent radiation-induced cancer.

Limitations

This study is subject to the limitations inherent to retrospective observational data studies. The status of each bypassed graft assessed by MDCT was not confirmed by selective coronary angiography. One of major limitations of our study is that MDCT evaluations were done by a single radiologist rather than by multiple blinded reviewers. The categorization of graft patency in this study thus was not done in a rigorous sort of manner but rather was the subjective interpretation of a single reviewer. Arterial grafts with diffuse severe narrowing are readily apparent, but it can be rather difficult to differentiate a small-caliber RA graft from an RA graft with a diffuse narrowing. Further studies involving multiple blinded reviewers who use predefined patency criteria are needed to verify the results of our study.

Usually MDCT scanning was done after discharge from the intensive care unit. Thus only those patients who survived through the immediate postoperative period could have been selected for MDCT evaluation. Because of this selection, the study results may not be generalizable to all patients after CABG, especially to those who have critical postoperative courses.

CONCLUSIONS

A large proportion of RA grafts initially showing occlusion or poor opacification after CABG demonstrated patency restoration on serial MDCT. Larger target vessel size and target vessel stenosis of at least 90% were significantly correlated with this phenomenon. These results may help predict the prognosis of grafts that initially show occlusion or poor flow after CABG.

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